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DOMESTIC WATER USE IN PHOENIX, ARIZONA

Gerald M. Sullivan, et al

Robert A. Taft Sanitary Engineering Center
Cincinnati, Ohio

15 June 1959

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**Report to
THE FEDERAL HOUSING
ADMINISTRATION**

**DOMESTIC WATER USE
IN PHOENIX, ARIZONA**

June 15, 1959

PUBLIC HEALTH SERVICE...ROBERT A. TAFT SANITARY ENGINEERING CENTER

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FINAL REPORT TO

THE FEDERAL HOUSING ADMINISTRATION

Domestic Water Use

in

Phoenix, Arizona

by

Gerald M. Sullivan
Asst. Sanitary Engineer

James B. Coulter
Sr. Sanitary Engineer

Thomas W. Bendixen
Soil Scientist

June 15, 1959

PUBLIC HEALTH SERVICE
Robert A. Taft Sanitary Engineering Center
4676 Columbia Parkway
Cincinnati 26, Ohio

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INTRODUCTION

The Federal Housing Administration has in recent years become increasingly aware of the pressing need for improvement in household sewage disposal systems. As a result, the FHA sponsored a project, undertaken by the Suburban Sanitation Section of the Robert A. Taft Sanitary Engineering Center, to develop practical design criteria for seepage pits and beds. Included in the contract was the commission to analyze the collected data for subsidiary information.

Careful consideration led to the selection of seven states for study areas, exhibiting wide diversities in such factors as climate, soil types, and construction requirements and practices. Field surveys were conducted and comprehensive data were obtained on all factors deemed pertinent to the design and function of individual disposal systems. Water meter records for each home, whenever available, were secured from the water company so that fairly accurate estimates of loading could be established for disposal systems.

Little has been published on the water used at individual homes of the subdivision class. Most of the available water use estimates are on a regional or city level and usually are made from water source records. They seldom isolate domestic use, but rather include the gamut of water uses. For this reason the water records which were collected, while indispensable for their primary use, are also of general interest in the fields of water supply and sewerage service.

An analysis of individual water meter records for about 240 homes in Phoenix, Arizona will be presented herein. The records were collected in eight subdivisions that range from 2½ years to 5½ years old.

Phoenix, the capitol of Arizona and seat of Maricopa County, lies in the Salt River Basin in the extreme southwestern portion of the country. With an estimated population of 171,000 in 1956, the city has nearly doubled since the 1950 census and continues to mushroom. Maricopa County has expanded in like proportions. Clear skies, mild winter temperatures, and extremely low humidity account in part for its phenomenal growth. Winter temperatures average 68°, relative humidity averages 38%, and the mean annual rainfall is less than 8 inches.

Domestic water use in Phoenix will be interesting when compared with published estimates for the area and other parts of the country. A rather unique feature of the data is that three of the eight subdivisions received water simultaneously from two sources: metered water from a water company for domestic use, and unmetered water from an irrigation authority solely for the purpose of lawn irrigation. This affords an opportunity to evaluate the effect of lawn care on water use.

The brief description of subdivisions contained in Table 1 will give a general picture of the area surveyed.

Table 1

Description of Subdivisions

Homes Using Only Metered Water

Symbol	Name of Subdivision	No. of Homes Surveyed	Avg. Home Age (yrs.)	Description	Avg. Lot Size (sq.ft.)
BC	Belden Courts	32	5.6	Medium price range; maintenance and care of lawn varies from no lawn and few shrubs to well kept lawns with many citrus and decorative plantings. Almost completely built up; few vacant lots.	6,800
CB	Campo Bello	17	2.7	Medium price range; semi-rural area with large lots; minimum amount of lawn care and shrubbery. Much undeveloped property; building continues.	36,900
EBA	East Broadway Additions	53	3.7	Average home is somewhat less than medium priced, with variety of homes in the high and low price groups. Great variety in plantings and yard maintenance. Subdivision development practically complete.	7,100
GP	Griffith Park	18	2.8	Higher priced homes; well established and maintained lawns. Many shrubs and citrus plantings. Development essentially complete.	6,300
MP	Maryvale Parks	57	4.5	Medium price range; lawn care probably not as meticulous as in Griffith Park. Development practically complete.	6,500

Table 1 (continued)

Description of Subdivisions

Homes Using Unmetered Lawn Irrigation Water

Symbol	Name of Subdivision	No. of Homes Surveyed	Avg. Home Age (yrs.)	Description	Avg. Lot Size (sq.ft.)
BC	Belden Courts	21	5.6	Identical to the Belden Courts previously described, except lawn water is from separate source.	6,800
MM	McLellan Manor	13	3.6	Comparable to Griffith Park, except that lawn water is from separate source.	8,900
SPH	Squaw Peak Heights	30	5.1	Comparable to Griffith Park, except that lawn water is from separate source.	10,400

DATA PROCESSING

In processing the Phoenix water use data, every effort was made to first derive statistics on the smallest practical unit of time which would be free from overlapping major influences. The units were then combined within categories and expanded to show what influence these factors had on water use in the area.

The first step in data separation was a review of water meter records for each home in conjunction with the general survey form completed during the Seepage Pit Study. From the history of occupancy, a determination was made as to the number of persons in the home for each month of record. Only those months of record were used in which occupancy was constant. With a definite occupancy thus assigned for every period, all Phoenix data were tabulated by family size. Within family size groups the data were further separated by subdivision, home, and calendar year showing water use by months. The breakdown of raw data is best described by an example of two homes in Maryvale Park, each having four occupants. The tabulation in Table 2 expresses the raw data for the periods during which these homes were occupied by four persons. The same homes would appear in other tabulations if there was a record of a different number of persons during some other period of time.

Table 2

Sample Tabulation

Four Person Homes (Main Grouping)

(All quantities are gallons per day)

Case No.	Maryvale Parks (Subgrouping)					
	hP-2				MP-3	
Bedrooms	3				3	
Year	1955	1956	1957	1958	1957	1958
Jan.	130	60	105	100		265
Feb.	205	165	115	155		275
March	465	285	445			
April	625	645	460			
May	735	1150	815		625	
June	1220	1190	1220		560	
July	525	605	640		365	
Aug.	755	675	525		375	
Sept.	550	405	450		430	
Oct.	240	115	90		170	
Nov.	135	85	120		205	
Dec.	100	75	130		290	
Winter (Dec., Jan., Feb.)						
Mean		108	98	128		277
Summer (June, July, Aug.)						
Mean	833	323	795		433	
Annual						
$\sum x$	5685	5455	5115			
$\sum (x^2)$	3,928,375	4,278,425	3,513,625			
Mean	474	454	426			
Std. dev.	335	404	348			

It should be noted that annual statistics for individual years were derived only when the full twelve months were recorded. Likewise, seasonal means were derived only if all three months of the season were recorded. Winter for a particular year was composed of January and February of that year and December of the previous year.

Summary calendars were prepared for each subdivision and for Phoenix as a whole, showing per capita water use by family size and for the combined population.

EFFECT OF OCCUPANCY

Having correlated water meter records with histories of occupancy, all Phoenix water data were tabulated and summarized by family size. Mean water use thus derived for each family size is presented in Table 3.

Table 3

Relation of Water Use per Home
to Number of Occupants

Occupants per Home	Winter (Dec., Jan., Feb.)			Summer (June, July, Aug.)			Annual		
	Sample Size	Mean gal/day	Std.Dev. of Mean	Sample Size	Mean gal/day	Std.Dev. of Mean	Sample Size	Mean gal/day	Std.Dev. of Mean
1	14	124	58	15	441	256	10	259	113
2	173	180	94	161	670	308	130	402	162
3	162	181	69	162	685	300	111	406	132
4	146	223	84	140	715	312	104	457	156
5	84	231	105	72	786	395	51	509	195
6	48	210	96	41	770	324	28	443	150
7	12	252	91	8	1035	189	6	566	168

Plots of mean water use per home versus the number of persons per home were made of the seasonal and annual data. From these plots linear equations were derived by the method of least squares. The resulting equations are as follows:

$$\text{Winter; } W_T = 144 + (16)(P)$$

$$\text{Summer; } W_T = 554 + (44)(P)$$

$$\text{Annual; } W_T = 332 + (29)(P)$$

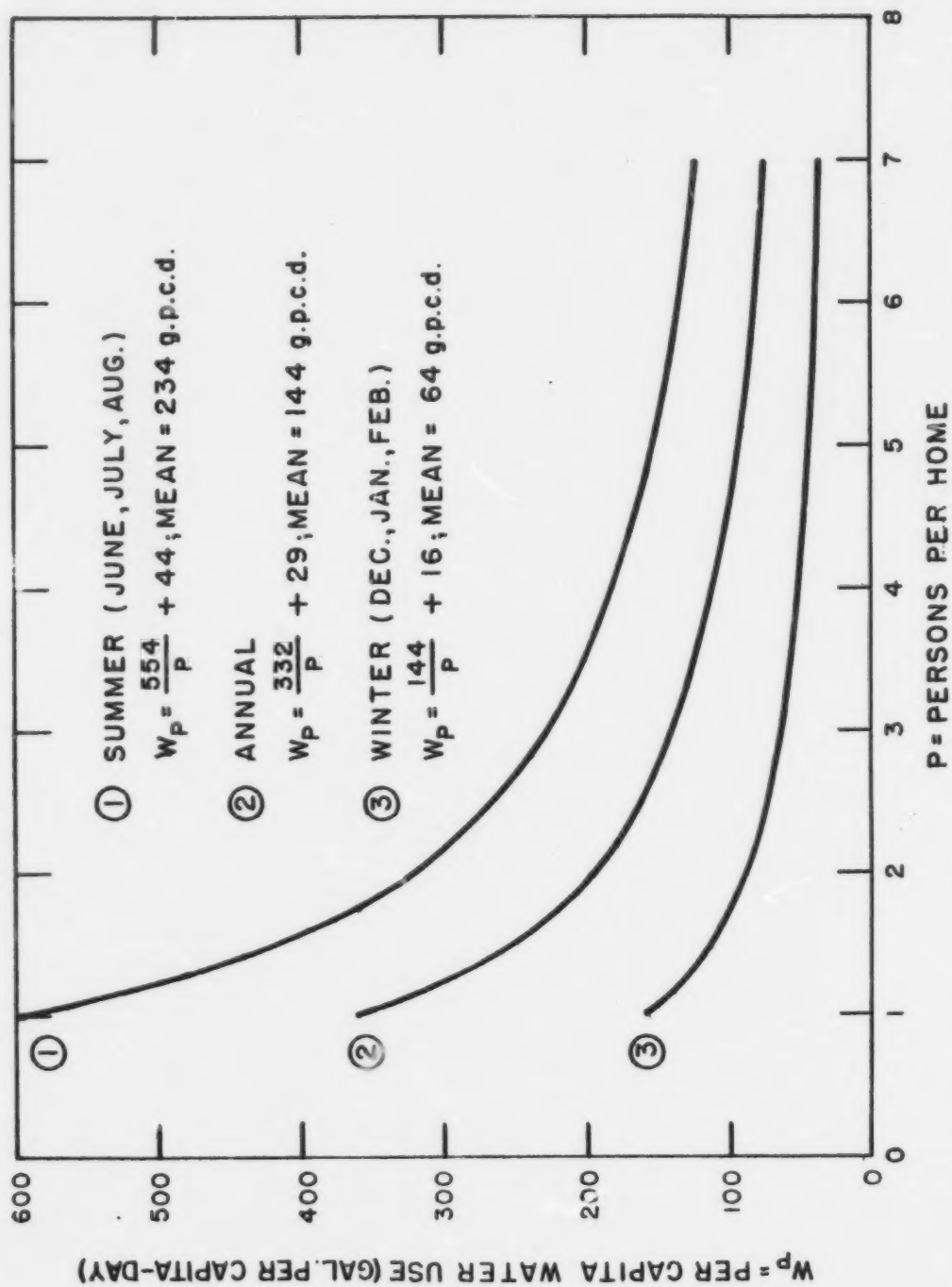
where: W_T = Total mean H_2O use in gal/home/day

P = No. of persons occupying home

When these expressions are reduced to the per capita basis, they assume the hyperbolic forms plotted in Figure 1. Approaching limits asymptotically, the curves illustrate the high per capita water use of small families and the more efficient use as family size increases.

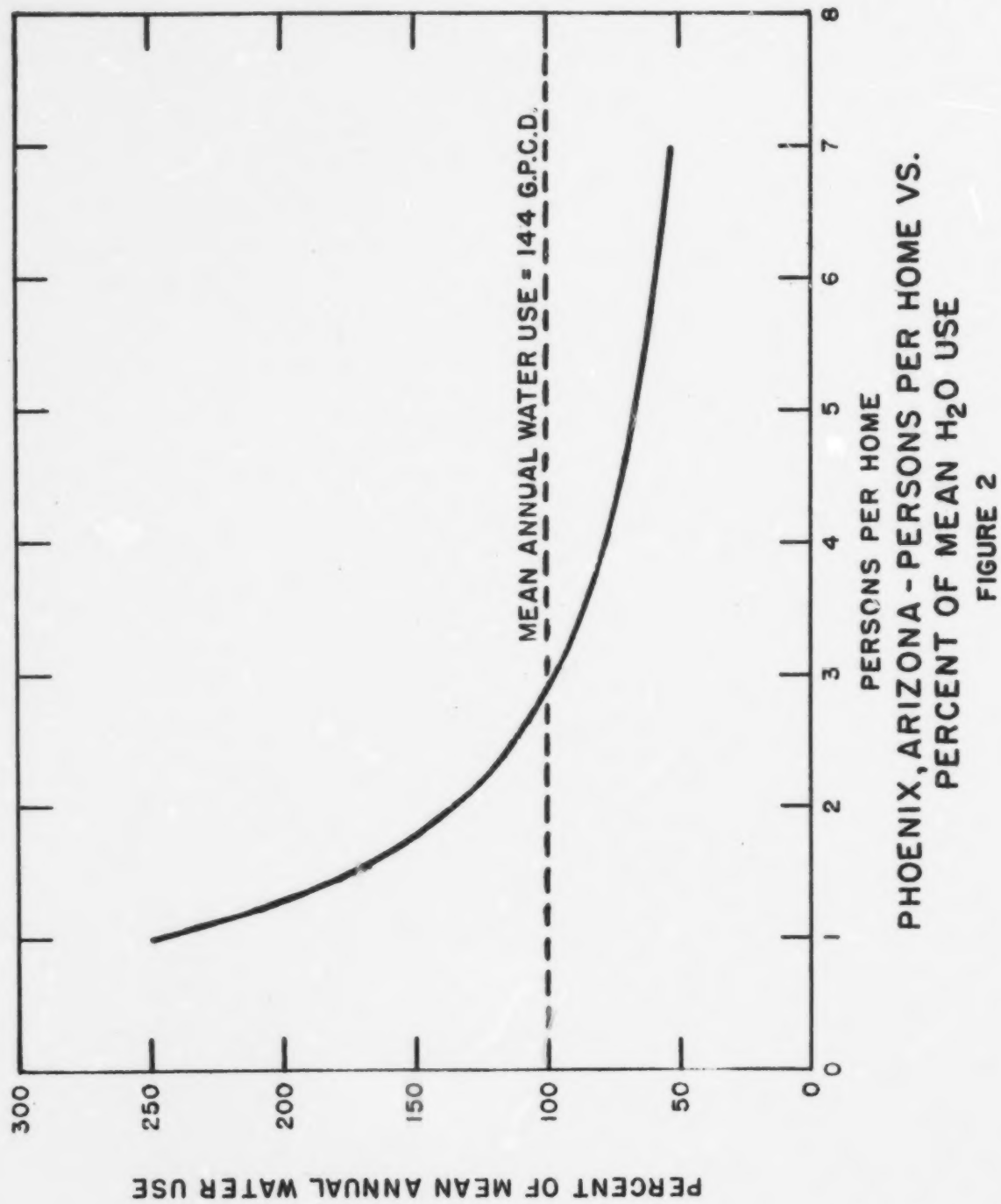
A more useful relationship evolves when values of water use for the various family sizes are plotted as percentages of the mean water use. This type of curve, based on the mean annual water use, is shown in Figure 2. Values thus obtained are expressed decimally as water use weighting factors (fw), and are presented for the seasonal bases in Table 4. The percentage relationship between per capita water use of a particular family size and the mean use of the total sample population for the same period is consistent throughout the year. This relationship should be independent of geographical location; however, derived weighting factors would be applicable to other areas only if their average family size were roughly equal to that of the study area.

A typical application of weighting factors might be in the design of an individual disposal system for a particular number of persons.



PHOENIX, ARIZONA - EFFECT OF OCCUPANCY ON WATER USE

FIGURE 1



Having the fw value and a measure of its variation, the mean water use of the area can be adjusted to arrive at a reasonable estimate of expected sewage flow.

Table 4
Weighting Factors, fw, for Number of
Persons Occupying a Home

Persons	Winter	Summer	Annual
1	2.50	2.56	2.51
2	1.38	1.37	1.35
3	1.00	0.98	0.97
4	0.81	0.78	0.78
5	0.70	0.66	0.66
6	0.63	0.58	0.58
7	0.58	0.53	0.53

EFFECT OF LAUNDRY HABITS

It has previously been mentioned that field survey teams, while conducting general surveys, sought detailed information on all factors pertinent to the function of soil absorption systems. One item receiving attention was the laundry loading for each home. Housewives were queried on such items as type and make of washer, type and amount of cleaning agent used, and the number of laundry loads washed per week. Due to changing circumstances within homes which would affect laundry practice, estimates of loading were considered valid only for a few months preceding the survey. December of 1957 was used in analyzing laundry data because it was the month closest to the date of survey for which complete water records were available. It also was desirable because water use was at a minimum and any effect of laundry water would, therefore, be more evident.

Water expended in washing a load of clothes differs between brands of the same type of washer, but this difference is slight in comparison to the total amount used. Therefore, the laundry data were separated by the major classifications of automatic and conventional washers without regard to manufacturer. This separation takes into account the basic difference in water use between the two types.

Theoretically, each load of wash per person per week should add approximately five gallons to the daily per capita water use. To evaluate the actual effect of laundry on water use, the data were separated by wash load ranges. Mean per capita water uses for the various ranges, divided by fw to correct for the number of persons in the homes, are shown in Table 5. Laundry data were considered for families washing less than three loads per person-week; data beyond this range were widely scattered and represented only 5% of the total sample.

Table 5

Loads/person-week	Automatic Washers			Conventional Washers		
	0-0.9	1.0-1.9	2.0-2.9	0-0.9	1.0-1.9	2.0-2.9
W_p/fw (gal/capita-day)	66	64	59	52	46	42
Std. Dev.	29	25	27	23	29	16

The downward trend exhibited in Table 5 is not statistically significant. Two factors tend to discredit the results: first, the increase in water use due to laundry is quite small in relation to the standard deviation between homes; second, the weighting factors used in adjusting for family size are not independent of laundry water.

The data were further separated and comparisons of laundry loading versus water use were made for families of the same size. This had the advantage of eliminating the confounding fw factor, but at the same time it reduced the number of observations in each group. Results of this comparison were erratic and yielded no correlation between laundry loading and water use.

In view of the variation in water use between homes, a very large sample would be required to demonstrate with confidence the effect of laundry habits on water use.

SEASONAL VARIATION

Average monthly water use of each subdivision is shown in Table 6. Phoenix exhibits the usual trend of continual increase from January until midsummer, although its water use is abnormally high throughout the year. Maximum water use generally occurs in June or July, with only the Belden Courts reaching a peak in September.

Natural differences in the pattern of living cause major variations in water use between subdivisions. Extent of lawn care is considered the most significant factor. This is especially obvious in the first group of subdivisions in Table 6. In those subdivisions where metered

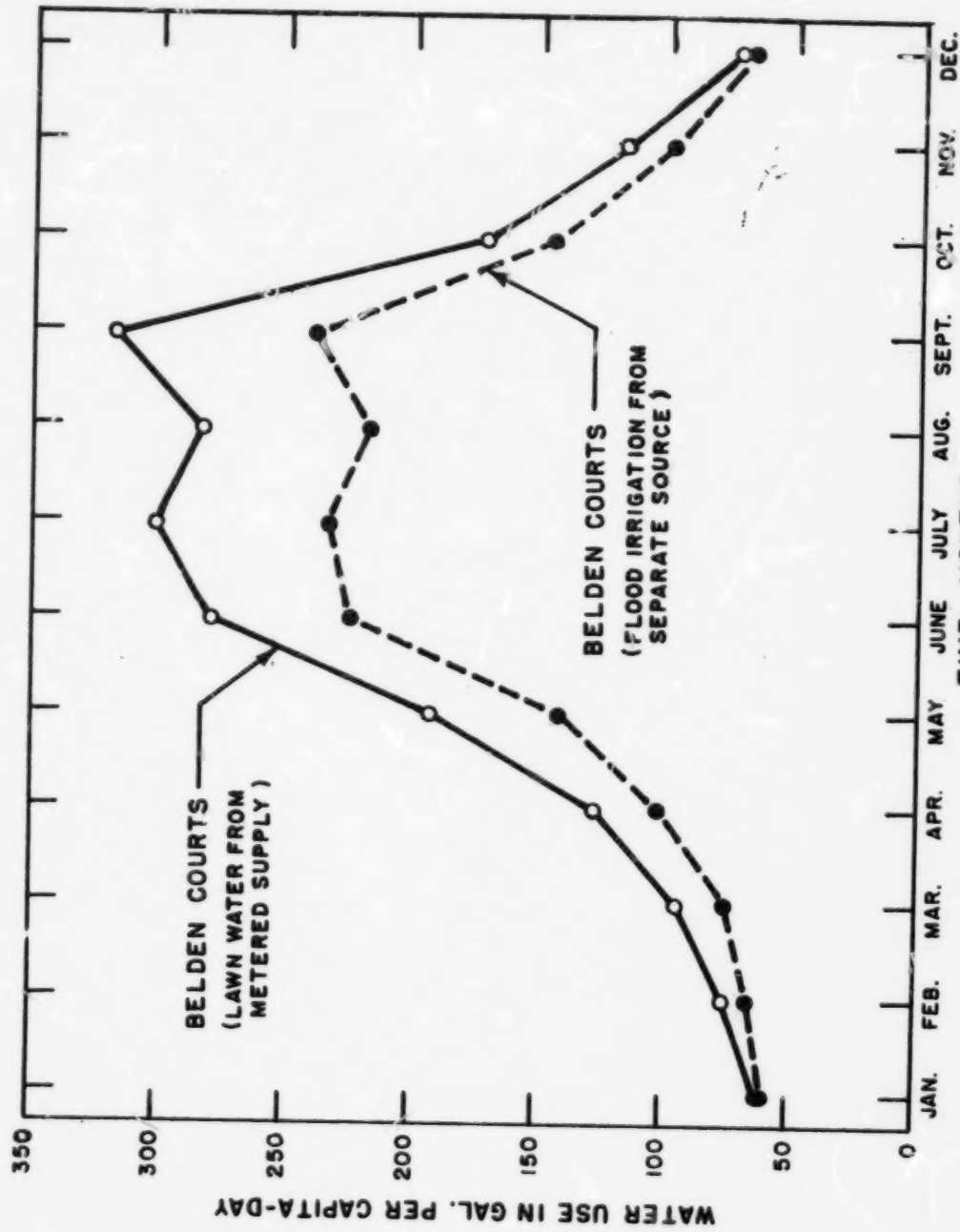
water was used exclusively, the amount of water used in the warmer months was closely related to the degree of lawn care exercised.

An evaluation of the effect of lawn watering is presented graphically in Figures 3 and 4. Each figure is a comparison of comparable groups of homes, one group using unmetered water for lawn irrigation, and the other group using metered water exclusively. The difference in ordinates between either set of curves for a particular month essentially represents that portion of water used for lawn irrigation during the month. Lawn watering becomes evident in either Figure beginning in March or April and ending in October or November. These periods agree generally with the long Phoenix growing season which averages 293 days per year.

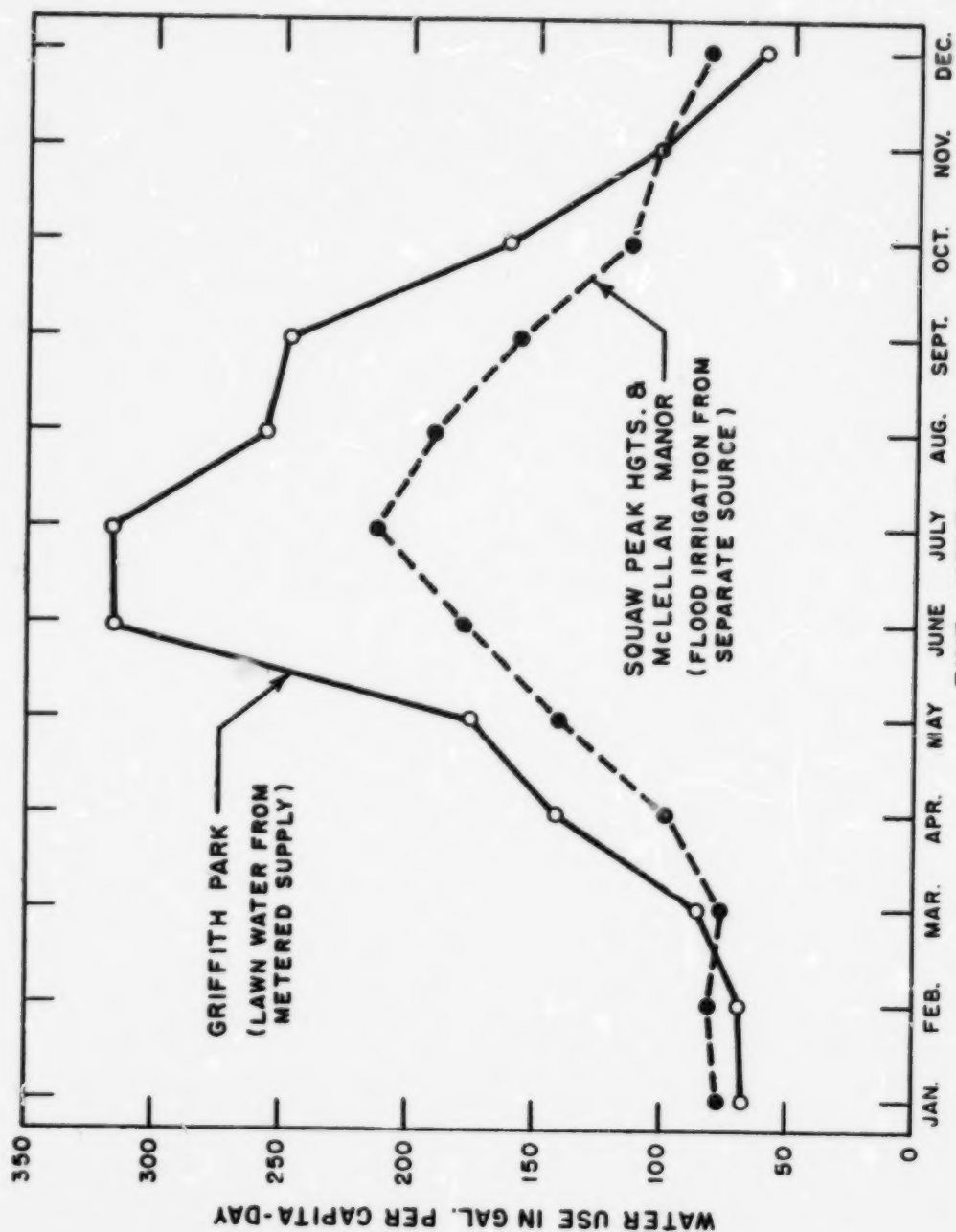
During the peak growing season of May through September, lawn watering in the Belden Courts (Figure 3) averages 63 gallons per capita-day. This accounts for an average increase in water use of 30% during the period, with the peak increase being 36% in May.

Comparing Griffith Park with Squaw Peak Heights and McLellan Manor for the same five month period, Figure 4 discloses that lawn water averages roughly 86 g.p.c.d. for these subdivisions. This causes an average increase of 49% in water use during the period, with a peak increase of 77% in June.

In Table 7 are shown the statistics of seasonal and annual mean water use for each subdivision and Phoenix as a whole. Extreme cases are found in any group, as evidenced by the wide ranges recorded in Table 7. However, the means and standard deviations are descriptive of the mass within subdivisions.



PHOENIX, ARIZONA - EFFECT OF LAWN WATER
FIGURE 3



PHOENIX, ARIZONA - EFFECT OF LAWN WATER

FIGURE 4

Although total water use varies widely among the subdivisions in summer, this variation is much less extensive on either the winter or annual basis. Mean summer water use for Phoenix as a whole is 234 gallons per capita-day, or 366% of the mean winter use. This difference in water use between seasons is quite extreme in comparison to other parts of the nation. Mean annual domestic water use for Phoenix as a whole is 144 gallons per capita-day.

Table 6
Mean Monthly Water Use by Subdivisions
in Gal/capita/day

	Homes using metered water for lawn irrigation					Homes using flood irrigation from unmetered source			All Phoenix Data Combined	
	BC	CB	EBA	GP	MP	BC	MM	SPH	Mean	Std. Dev.
Jan.	61	56	51	67	47	60	51	84	58	48
Feb.	75	54	65	68	72	66	70	83	70	42
Mar.	94	61	100	85	110	75	66	78	91	59
Apr.	127	96	148	141	173	102	109	108	131	84
May	192	136	210	174	228	141	136	141	182	116
June	278	208	311	314	246	223	153	185	250	147
July	300	151	259	315	164	232	204	215	233	155
Aug.	281	181	244	255	183	216	203	184	224	148
Sept.	315	175	161	246	103	238	162	154	197	142
Oct.	172	87	98	161	64	144	82	123	119	92
Nov.	116	65	72	102	50	98	81	108	86	72
Dec.	72	55	64	61	48	66	60	88	64	43

Table 7
Variation in Mean Seasonal Water Use
in Gal/capita/day

Subdivision	Winter (Dec., Jan., Feb.)			Summer (June, July, Aug.)			Annual		
	Mean	Std. Dev.	Range	Mean	Std. Dev.	Range	Mean	Std. Dev.	Range
BC	70	35	16-176	284	144	66-810	171	78	40-383
CB	55	33	17-182	189	100	38-423	115	58	39-240
EBA	63	40	16-219	264	162	29-846	151	79	49-412
GP	65	36	25-246	304	145	54-846	170	68	89-420
MP	56	29	16-350	193	101	26-655	124	61	52-402
* BC	63	25	17-134	222	107	65-602	140	58	50-306
* MM	66	35	27-147	181	120	35-472	97	50	33-211
*SPH	87	66	36-415	201	171	22-779	142	89	50-450
Phoenix Subdivisions Combined	64	37	16-415	234	138	22-846	144	73	33-450

*Homes using unmetered water for lawn care.

GENERAL DISCUSSION

Mean annual water use in the United States in 1955, as estimated by K. A. MacKichan⁽¹⁾, was 148 gallons per capita-day. More specifically, MacKichan estimates water use in the Colorado River Basin as 175 g.p.c.d. and the U. S. Public Health Service⁽²⁾ estimates 190 g.p.c.d. for the city of Phoenix. These estimates are derived from water source records and include domestic, industrial, and municipal use plus leakage.

Analysis of the water records from the subdivisions under consideration revealed an annual average domestic use of 144 g.p.c.d., roughly 76% of the total per capita use estimate for Phoenix. This is a wide

divergence from the commonly accepted rule-of-thumb which considers domestic water use as roughly 35-45% of the total use in cities.

Many factors besides climate or geographical location have influence on the balance of water use between the different consumers. The type and size of community, economic level, and the cost, quality and availability of water, among other factors, are also significant. Water use estimates for a specific suburban area may be grossly in error if taken directly from estimates for the encompassing region. Phoenix has served as a case in point.

References

- (1) MacKichan, K. A., "Estimated Use of Water in the United States, 1955." U. S. Dept. of Interior Geological Survey Circular 398, Washington, D. C. (1957)
- (2) U. S. Public Health Service, "Municipal Water Facilities - Communities of 25,000 Population and Over, Continental United States and Territorial Possessions as of December 31, 1956." Washington, D. C. (1957)